MATHEMATICAL
CONTENTS

Department of Computer Engineering, UET Taxila

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INFORMATION AND COMMUNICATION SYSTEM/COMPUTING FUNDAMENTALS

Instructor: Dr. Sanay Muhammad

1. Binary number system
2. Octal number system
3. Hexadecimal System
4. Conversion of One number system into another.
5. Complement of a Number
6. Binary Addition and Subtraction

CIRCUIT ANALYSIS

Instructor: Engr. Asim Raza

Week	Topic Covered	CLO No.	Assessment (if Any)	Learning Domain (Cognitive, Affective, Psychomotor)	Level of learning (1-6)	Related Contents of Mathematical Subjects
1	Basic concepts, charge, current, voltage, power, resistance. Ohm's Law, Kirchhoff's Laws, Single-Loop Circuits, Single-Node-Pair Circuits	1		Cognitive	2	**CAG:** Analytical Geometry, Functions Limit and Continuity:
2	Series and Parallel Resistor Combinations, Circuits with series parallel combinations of resistances Wye-Delta transformations, Circuit with dependent sources.	1, 2		Cognitive	2, 4	**Linear Algebra:** Echelon form, Gauss elimination mthod, inverse of a matrix
3	Nodal Analysis: for circuits containing only independent and dependent current, voltage sources	1, 2		Cognitive	2, 4	**As above**
4	Loop Analysis: for circiuits containing only independent and dependent current, voltage sources	1, 2		Cognitive	2, 4	**As above**
5	Concept of Equivalence and Linearity and Superposition Theorem	1, 2		Cognitive	4	**As above**
6	Thevenin and Norton Theorem For Independent Sources, dependent Sources and both dependent and independent sources	1, 2		Cognitive	4	**As above**
7	Source Transformation, Maximum Power Transfer	1, 2		Cognitive	4	**As above**
8	Op-Amp Models, Ideal Op Amp, Fundamentals Op-Amp circuits	1, 2		Cognitive	4	**As above**
9	Operational Amplifier Circuits	1, 2		Cognitive	4	**As above**

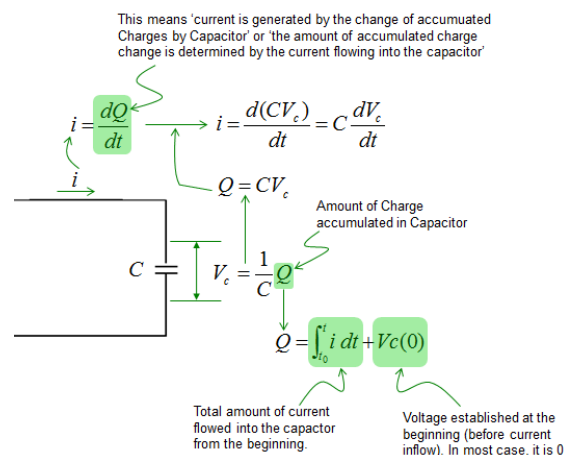| 10	Introduction to Capacitors and Inductors, Series and Parallel Combinations	**1, 3**		Cognitive	**3**	**CAG:** Differentiation and Integration
11	First Order RL and RC Circuits: Differential Equation Method and Step by Step Method	**1, 3**		Cognitive	**3**	**CAG:** Differentiation and Integration **DE:** Basic Concepts and Modelling, Analytical Methods of Solution for First-order ODEs
12	Second order transient circuits, Over Damped Response	**1, 3**		Cognitive	**3**	**DE:** Mathematical Models Based on Second-order ODEs, Analytical Methods of Solution for Second-order ODEs
13	Second order transient circuits, Under Damped, Critically Damped Response.	**1, 3**		Cognitive	3	**As above**
14	Sinusoidal and Complex Forcing Functions, Phasors Phasor Relationships for Circuit Elements , Impedance and Admittance Phasor Diagrams	**1, 4**		Cognitive	**4**	**CVT: Introduction** Review of complex numbers, Complex valued functions, Elementary functions, Limits and continuity, Applications in Engineering
15	Basic Analysis Using Kirchhoff's Laws, Analysis Techniques 1	**1, 4**		Cognitive	**4**	**As above**
16	Basic Analysis Using Kirchhoff's Laws, Analysis Techniques 2	**1, 4**		Cognitive	**4**	**As above**

ELECTRONICS CIRCUITS

Instructor: Engr. Malik M. Asim

Today more than ever, electronics are an integral part of our everyday lives. But behind each and every electrical appliance or device, no matter what task it was designed for, lies a vast system of electrical components that must function as a whole. Each component (resistors, capacitors, inductors, etc.) has specifications of their own, as does the final product that they are a part of, so engineers must design their devices to meet not only their intended purpose, but so that the individual components are within their tolerances. Vital to this is the analysis of currents and voltages throughout the electrical circuit.
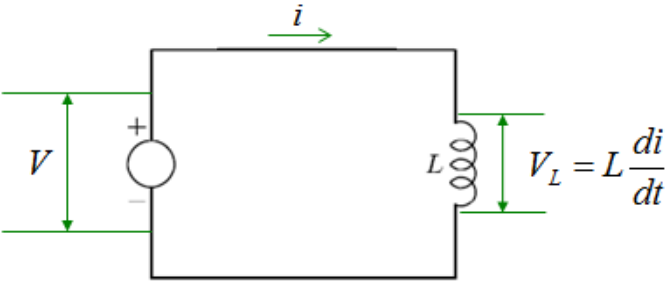
Perhaps one of the most apparent uses of linear algebra is that which is used in Electrical Engineering. Systems of equations introduced in math class is mostly used to solve circuits involving electrical components. There, the resistor, voltage source and capacitor take the stage as well as their accompanying language consisting of Kirchoff and Ohm. With the basic concepts down, math class is resumed and students can look forward to playing with N number of equations with N number of unknowns. To solve for the currents and voltages, students can use simplification and substitutions.

The *V-I* relation for an inductor or capacitor is a differential. A circuit containing an inductance L or a capacitor C and resistor R with current and voltage variable given by differential equation of the same form. It is a linear first order differential equation with constant coefficient when the value of R,L,C are constant. L and C are storage elements. Circuit has two storage elements like one L and one C are referred to as second order circuit. Therefore, the series or parallel combination of R and L or R and C are first order circuit and RLC in series or parallel are second order circuit.

Capacitor:

Inductor:

Voltage Generator(positive sign)

Voltage Drop (negative sign)

$$V + (-V_L) = 0$$

This means "the direction of voltage built up accorss the inductor is always oposite to the direction of the applied voltage

$$V = V_L = L\frac{di}{dt}$$

In the diagram: $V_L = L\frac{di}{dt}$

DIGITAL LOGIC & DESIGN

Instructor: Engr. Noshina Ishaaq

Logic circuits are the basis for modern digital computer systems. To appreciate how computer systems operate it is required to understand digital logic and Boolean algebra and these contents comes from discrete structure.

DISCRETE STRUCTURES

Instructor: Engr. Tariq Javed

1. Logic and Set Theory

2. Probability

3. Number Theory

4. Abstract Algebra

5. Combinatorics

6. Graph and Game Theory

COMPUTER COMMUNICATION & NETWORKS

Instructor: Dr. Aasim Raheel

A solid math background is valuable, like all the other computer science and engineering fields. In addition to Calculus, important tools in computer networking and communications include the following: Linear algebra, probability, and statistics. Understanding queue behavior helps to develop a strong intuition about traffic engineering and ordinary tasks like sizing protection paths and assigning bandwidth to activities and channels. Graph theory basics are useful, to understand routing protocols and topology generation.

CONTROL ENGINEERING

Instructor: Dr. M. Asif Khan

index	Topic Covered	Mathematical Content	CLO #	Level of learning (1-6)
1	Introduction to Control Engineering, Historical development to modern control theory	N.A	1	1
2	Features and configuration of control system, analysis and design objectives	N.A	1	1

3	Modeling in frequency domain I	• Calculus and analytical geometry
		  o Power series and Taylor series
		  o Laplace transform
		• Differential Equations
		• Systems of linear equations
		• Numerical Analysis
		  o Error analysis and interpolation
		  o System of linear equations
			2	3

5	Modeling in time domain I	• Numerical analysis
		  o Numerical Methods for computing Eigen values
		  o numerical differential
		  o system of linear and nonlinear equations
		• Linear Algebra
		  o Vector spaces and transform
		  o Eigen values eigen vectors
		  o Linear programming
			2	3

8	Time response of first order system and higher order systems	• Differential equations First and second order	3	4
10	Reduction of multiple subsystem	• Differentiation	2	4

		• Discrete structures • Similarity transform		
12	Stability control system	Calculus and analytical geometry concepts	**3**	**4**
14	Root Locus Technique	Complex transforms + vector spaces	**3,4**	**4,5**
16	PID Controller Design	Vector spaces and complex transforms	**4**	**5**

WIRELESS & MOBILE NETWORKS

Instructor: Dr. Farhan Qamar

1. Probability & Statistics

Probability is a measure of the likelihood of an event to occur. Many events cannot be predicted with total certainty. We can predict only the chance of an event to occur i.e., how likely they are to happen, using it. Probability can range in from 0 to 1, where 0 means the event to be an impossible one and 1 indicates a certain event.

Application of Probability methods in Wireless communication & mobile networks:

In communications, trunking is a technology for providing network access to multiple clients simultaneously by sharing a set of circuits, carriers, channels, or frequencies, instead of providing individual circuits or channels for each client. Due to the limited number of channels shared between so many users, there is always a chance of blockage (no network access) in the network. The problems of finding chances of blockage for the users due to limited resources in the network can be solved by using probability methods.

2. Calculus & Analytical Geometry

a. Integration

In mathematics, an integral assigns numbers to functions in a way that describes displacement, area, volume, and other concepts that arise by combining infinitesimal data. The process of finding integrals is called integration. Along with differentiation, integration is a fundamental, essential operation of calculus, and serves as a tool to solve problems in mathematics and physics involving the area of an arbitrary shape, the length of a curve, and the volume of a solid, among others.

Application of Integration in Wireless communication & mobile networks:

One of the most elementary tasks in the cellular system design is propagation modeling and coverage prediction. In wireless communication and mobile networks, a variety of approaches have been used to predict coverage areas using propagation models. These models are helpful in predicting path loss or signal attenuation, thus enabling acceptable reception. Cellular designers usually use advanced planning tools for network coverage estimation. The coverage estimation is based on terrain data combined with a propagation model. Integration is used to combine the terrain data from multiple points to estimate the overall coverage area of Base station.

b. Differentiation

Differentiation, in mathematics, process of finding the derivative, or rate of change, of a function or Differentiation is all about finding rates of change of one quantity compared to another. We need differentiation when the rate of change is not constant.

Application of Differentiation in Wireless communication & mobile networks:

In wireless communication, due to free space propagation the loss of signal power is not constant. To find the rate of change of signal power at any point we use derivatives in different propagation models.

Derivatives are also used in frequency and phase modulation techniques. For phase modulation, the phase is proportional to the modulating signal whereas in frequency modulation the derivative of phase is proportional to the modulating signal. Thus, derivatives are used to find the rate of change of phase of signal or to define instantaneous frequency.

3. Matrices

In mathematics, a matrix (plural matrices) is a rectangular array or table of numbers, symbols, or expressions, arranged in rows and columns.

Application of Matrices in Wireless communication & mobile networks:

Walsh Codes also known as "Walsh-Hadamard code," it is an algorithm that generates statistically unique sets of numbers for use in encryption and cellular communications, known as "pseudo-random noise codes,". Walsh codes are also used in direct sequence spread spectrum (DSSS) systems such as Qualcomm's CDMA. In short, Matrices are used to define the Walsh codes for encryption in 3G networks.

ARTIFICIAL INTELLIGENCE

Instructor: Dr. Afshan Asim

Linear Algebra

Vectors

definition, scalars, addition, scalar multiplication, inner product (dot product), vector projection, cosine similarity, orthogonal vectors, normal and orthonormal vectors, vector norm, vector space, linear combination, linear span, linear independence, basis vectors

Matrices:

Definition, addition, transpose, scalar multiplication, matrix multiplication, matrix multiplication properties, hadamard product, functions, linear transformation, determinant, identity matrix, invertible matrix and inverse, rank, trace, popular type of matrices- symmetric, diagonal, orthogonal, orthonormal, positive definite matrix

Eigenvalues & eigenvectors:

Concept, intuition, significance, how to find

Principle component analysis:

Concept, properties, applications

Singular value decomposition:

Concept, properties, applications

Calculus

Functions

Scalar derivative

Definition, intuition, common rules of differentiation, chain rule, partial derivatives

Gradient

Concept, intuition, properties, directional derivative

Vector and matrix calculus

How to find derivative of {scalar-valued, vector-valued} function wrt a {scalar, vector} -> four combinations- Jacobian

Gradient algorithms

Local/global maxima and minima, saddle point, convex functions, gradient descent algorithms- batch, mini-batch, stochastic, their performance comparison

Probability

Basic rules and axioms

Events, sample space, frequentist approach, dependent and independent events, conditional probability

Random variables- continuous and discrete, expectation, variance, distributions- joint and conditional

Bayes' theorem, map, mle

Popular distributions- binomial, bernoulli, poisson, exponential, gaussian

Conjugate priors

Logic and Set Theory

Propositional logic

First order logic

SOFTWARE ENGINEERING

Instructor: Dr. Fawad Hussain

Since the course of software engineering that is taught in curriculum is only to teach students all the phases of Software development Life Cycle (SDLC). To make them understand each phase and in a moderate depth about various methods/ processes that are used in each phase. Since the objective of this course is not the in-depth development of software where the mathematical models may get involved. There is no direct mathematical part relevance to this course.

PROJECT MANAGEMENT

Instructor: Dr. Fawad Hussain

The main objective of this course is to present students with a knowledge of each and every step to manage a project, i.e., from the conception phase to the closeout phase. The math content that can be related to this course is some very basic algebra as well as some portion of financial mathematics (i.e., interest rate calculation, IRR, Earned Value Management, NPV (Net present value) etc) used during project selection, cost estimation, duration estimation etc.

NEURAL NETWORKS AND FUZZY LOGIC

Instructor: Dr. Sanaye Muhammad

Linear Algebra

Vectors

definition, scalars, addition, scalar multiplication, inner product (dot product), vector projection, cosine similarity, orthogonal vectors, normal and orthonormal vectors, vector norm, vector space, linear combination, linear span, linear independence, basis vectors

Matrices

definition, addition, transpose, scalar multiplication, matrix multiplication, matrix multiplication properties, hadamard product, functions, linear transformation, determinant, identity matrix, invertible matrix and inverse, rank, trace, popular type of matrices- symmetric, diagonal, orthogonal, orthonormal, positive definite matrix

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Random variables- continuous and discrete, expectation, variance, distributions- joint and conditional

Bayes' Theorem, MAP, MLE

Popular distributions- binomial, bernoulli, poisson, exponential, gaussian

Conjugate priors

Miscellaneous

Information theory- entropy, cross-entropy, KL divergence, mutual information

Markov Chain- definition, transition matrix, stationarity